ORIGINAL ARTICLE

CONTENTS

Complex diagnostics and prognostication of temporomandibular joints diseases using condylography

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ABSTRACT

Aim: To increase the efficiency of diagnosing diseases of the temporomandibular joint by assessing a set of condylographic indicators and developing prognostic algorithms for the course and an optimized program of dental care for patients.

Materials and Methods: A clinical retrospective cross-sectional comparative study was conducted with the participation of 470 patients with temporomandibular joint pathology aged 18–76 (33 ± 12.9) years. The comprehensive examination included palpation of the masticatory muscles and temporomandibular joint, condylography, computed tomography, teleradiography, occlusiography, analysis of mandibular mobility, modeling of the jaws in the articulator, as well as logical and statistical data processing using standard methods ($p<0.05$).

Results: The analysis of diagnostic and therapeutic approaches to patients with temporomandibular joint diseases allowed us to develop mathematical prognostic models and propose an examination program that takes into account the specifics of the development and course of the pathology. The algorithms for predicting the course of temporomandibular joint diseases based on complex clinical, condylographic and articulation methods were substantiated, which allowed to improve the dental care of patients.

Conclusions: A modified program for diagnosing patients with the use of mathematical modeling (Wald's method of sequential analysis) was proposed to assess the probability of progression of temporomandibular joint diseases. Further research will focus on expanding the primary data base, improving mathematical models, testing individualized prognostic algorithms and evaluating their clinical effectiveness.

KEY WORDS: temporomandibular joint disorders, condylography, dentition defects, pain, splint, dentures

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INTRODUCTION

The temporomandibular joint (TMJ) is one of the most complex joints in the human body, prone to the development of various pathological conditions that can cause pain, discomfort and significantly reduce the quality of life of patients [1–4].

Disorders of TMJ have been an urgent problem of modern dentistry for several decades [2, 5, 6]. The urgency of the problem is due to the increasing prevalence of the pathology (5–12 % of the population) and its significant impact on the daily life of patients, comorbidity with other diseases, the risk of serious anatomical deformities and functional disorders, chronic pain syndrome, difficulties in therapy, etc. [3, 4, 7–9].

Among the modern diagnostic methods, axiography (condylography) is becoming increasingly widely used both in clinical practice and in scientific research, allowing an objective assessment of the motor activity and functional state of the TMJ [10–15]. With the help of condylography, it is possible to obtain accurate information about the characteristics of movement and the structural condition of the joint, which is important for predicting the development of pathological changes [13, 16–18]. The method allows detecting even minimal deviations in motor function, which can be a harbinger of serious disorders. In addition, condylography helps to objectively monitor the effectiveness of treatment measures and plan individualized therapy for each patient [18–27]. However, in order to achieve maximum diagnostic accuracy, condylography should be combined with other examination methods to provide a comprehensive approach to assessing the patient's condition.

AIM

The aims of the study was to increase the efficiency of diagnosing diseases of the temporomandibular joint by assessing a set of condylographic indicators and developing prognostic algorithms for the course and an optimized program of dental care for patients.

MATERIALS AND METHODS

A clinical retrospective cohort comparative cross-sectional study was conducted.

Diagnosis and treatment were performed and the medical records of patients aged 18 to 75 (33±12.9) years, who were examined and treated in 2017-2025 at various medical institutions, were analyzed. The study involved 470 patients (150 men, 320 women) with TMJ diseases.

The comprehensive examination examined clinical, anamnestic and physical symptoms (in particular, with palpation of the masticatory muscles and temporomandibular joints, range of motion of the mandible, etc.), axiography (condylography), occlusiography, analysis of jaw models in the articulator, computed tomography, teleradiography, mathematical prognostic modeling, etc.

The results of condylographic studies in the first cross-sectional examination were analyzed in 100 patients (35 men, 65 women), in the second cross-sectional examination for 1 year – in 11 patients (5 men, 6 women).

The qualitative parameters were presented in the form of absolute values and relative indicators (in percent). For paired intergroup comparison, the Fisher angular transformation method was used.

Quantitative indicators were evaluated by analyzing the central tendency, variability, probability of paired intergroup differences and correlations, taking into account the nature of the data distribution. In the case of a normal distribution, the arithmetic mean, standard deviation, Student's test, and Pearson's correlation coefficient were determined. In the case of a distribution that deviates significantly from the normal distribution, the median, upper and lower quartiles, Mann-Whitney U test, and Spearman correlation coefficient were used.

A comparative analysis of the distribution of individual clinical criteria in the groups was performed using the Wald sequential analysis [28]. This made it possible to determine the diagnostic value, prognostic value, the strength of the influence of factors on intergroup differences in indicators and prognostic coefficients. The main criteria for assessing the prognostic significance of clinical signs were the strength of the factor's influence (η^2, %) and its informativeness (P, bits), which were calculated according to the standard method [29].

To assess the clinical effectiveness (practical applicability) of the developed algorithms for predicting the progression of TMJ diseases, the following indicators of predictive power were used sensitivity (ratio of true positive (TP) to the sum of true positive and false negative (FN) results), specificity (ratio of true negative (TN) to the sum of true negative and false positive (FP) results), positive predictive potential (PPP, ratio of true positive (TP) to the sum of true positive and FP results), negative predictive potential (NP) – ratio of TP to the sum of TN and FP.

For all statistical calculations, results with $p < 0.05$ were considered significant. In the case of multiple comparisons, the Bonferroni correction was used, according to which the critical value of the p level was determined as the product of the threshold value ($p = 0.05$) and the number of comparisons.

The study database, calculation of derived indicators, analysis of frequency characteristics, and diagramming were performed using Microsoft Excel software from the Microsoft 365 package (https://www.office.com/, corporate license). StatSoft Statistica 8 software (http://statsoft.com/, license STA862D175437Q) was used for statistical calculations [29].

The dissertation research is an integral part of the complex research work on the topic: "Clinical and experimental substantiation of diagnostics and orthopedic treatment of patients with diseases of the maxillofacial area".

RESULTS

In order to use the results of the study for risk stratification based on clinical (anamnestic, physical), psychosocial, and condylographic indicators, the parameters of their prognostic value and strength of influence were calculated (Table 1).

Based on the analysis of the frequency of individual factors and the prognostic value of each of the criteria, a method (algorithm) for assessing the likelihood of progression of TMJ disease was developed.

For each studied indicator, its presence or absence is determined, after which the corresponding values of informativeness are summarized (Fig. 1).

The threshold amount for choosing one of the two hypotheses was 19.8, which was determined by the formula $1-\alpha/\beta$, α is a first-order error (omission of the development of an undesirable outcome, chosen with greater rigor at the level of 0.01), and β is a second-order error (false prediction of an undesirable outcome, chosen with less rigor at the level of 0.05).

Reaching the threshold sum of prognostic coefficients allows the scale to determine the risk group:

- if the sum of prognostic coefficients is -19.8 or less, the risk of progression of TMJ disorders is high;
- if the sum of the prognostic coefficients exceeds -19.8 but is less than 19.8, the risk of progression of TMJ disorders is considered uncertain;
- if the sum of prognostic coefficients is equal to or greater than 19.8, the risk of progression of TMJ disorders is low.

The actual prognostic power of the proposed method (algorithm) for assessing the likelihood of progression of TMJ diseases was determined by the results of a one-year follow-up. During the observation period, a high prognostic risk was detected in a statistically significant number of cases ($p=0.01$). In cases of actual development and progression of disorders, the risk was assessed as high in most observations, with no cases of erroneous assessment of the risk as minimal (Table 2).

Among those who were not predicted to progress and did not actually progress, the percentage of concordance in risk assessment was 50% (50% vs. 0%, $\varphi = 2.5$; $p < 0.01$). False high-risk diagnosis was recorded in 25% of cases (25% vs. 86%, $\varphi = 2.1$; $p < 0.05$).

For the purpose of practical clinical testing and implementation of the developed method, a computer program was created – a web application with a data entry form and functionality for automatic calculation of prognostic values. For ease of integration into clinical practice, the program was implemented on the WordPress platform as a plugin:

- data entry form – the interface for data entry is built using HTML and JavaScript, all indicators indicated in the table are presented in the form of drop-down lists and checkboxes, which avoids input errors;
- prognostic values calculation – implements the function of calculating the sum of prognostic coefficients based on the entered data, comparing the entered indicators with prognostic coefficients according to the ranking table

(riskSum += coefficients["pain_snshs"][form["pain_snshs"].value]);

- output of results – based on the calculated amount, the program automatically determines the risk group and displays the output in a convenient format on the user's screen;
- integration into WordPress – the program is developed as a plugin for WordPress, which allows it to be used on the websites of medical institutions; the form and data processing logic are integrated through the shortcode [risk_assessment_form], which can be placed on any page of the site.

The structure of the plugin includes PHP scripts (for form processing and data transfer), JavaScript (for real-time calculations), CSS (for interface design).

The developed program allows to standardize the process of stratifying the risk of progression of TMJ diseases. Its advantages are automation (and reducing the likelihood of errors in calculations), convenience (intuitive interface provides quick data entry), and accessibility (integration into WordPress allows you to use the program without the need for additional training or installation of specialized software).

The calculation of prognostic coefficients and risk determination using the program demonstrated full compliance of the results with the findings obtained during clinical observation.

DISCUSSION

Early diagnosis and prevention of TMJ diseases are important for the timely selection of effective treatment tactics (conservative or surgical), improvement of prognosis and prevention of complications [10, 11]. The problem of TMJ is multidisciplinary, covering dental and interdisciplinary aspects [12–14].

Despite significant progress in the study of TMJ pathologies, the problem of predicting their progression remains difficult due to the lack of universal risk assessment methods. Studies aimed at identifying criteria and parameters that allow determining the likelihood of development and progression of TMJ diseases are relevant. The novelty of this problem is the search for more accurate and reliable methods of diagnosis and prognosis, which allow timely and effective measures to prevent complications [21–23].

A promising area is the use of machine learning technologies and clinical decision support systems, as artificial intelligence can significantly improve the accuracy of diagnosis and optimize the choice of therapeutic tactics [24, 25].

Assessment of the probability of progression of TMJ pathology opens up new opportunities for its understanding and effective management. Although a number of studies, including ours [26, 27] have contributed to the development of appropriate methods, many issues remain unresolved. This emphasizes the importance of further research to improve the efficiency of diagnosis of TMJ diseases.

Combining quantitative condylography with comprehensive clinical, radiographic and psychosocial assessment yields a diagnostically richer picture of TMJ disorders than any single modality. The sequential Wald-based algorithm reliably separates high-, indeterminate- and low-risk trajectories, reaching sensitivity

Table 1. Prognostic indicators of clinical, psychosocial, condylographic indicators in patients with diseases of the temporomandibular joints (TMJ)

Factor rank	Clinical indicators, units of measurement	Gradations	p	Predictive value (pat)	Strength of impact (%)
	Pain in the TMJ area	Yes	<0.01	-9.1	18
		No		+4.6	
	Quality of movement according to condylography	Bad	<0.05	-3.6	17
		Moderate		+1.7	
		Good		+4.6	
	Pain during wide mouth opening	Yes	<0.01	-4.5	16
		No		+2.7	
	Average speed outside the normal range	Yes	<0.05	-4.5	15
		No		+4.3	
	Noises in the TMJ area	Yes	<0.01	-4.2	12
		No		+2.2	
	The desire to find the most comfortable position of the jaws when closing the teeth	Yes	<0.05	-5.7	10
		No		+1.5	
	Impaired chewing, diction	Yes	<0.05	-2.1	9
		No		+3.7	
	Asymmetry of movements of the lower jaw in the horizontal plane	Yes	<0.05	-2.2	9
		No		+1.8	
	Treatment with the use of a corrective mouthguard in history	Yes	<0.05	-2.8	9
		No		+2.2	
	Intersection of graphs of a condylogram (axiogram)	Yes	<0.05	-2.3	8
		No		+3.5	
	Bifurcation of condylogram (axiogram) graphs	Yes	<0.05	-2.5	7
		No		+3.1	
	Teeth grinding or clenching	Yes	<0.05	-2.3	7
		No		+2.9	
	Chronic pain in the temporal region	Yes	<0.05	-2.2	6
		No		+5.7	
	Severe sensitivity in the dental area	Yes	<0.05	-2.2	5
		No		+1.9	
	The angle of the sagittal articular path is outside the normal range	Yes	<0.05	-2.2	5
		No		+2.1	
	The angle of the transverse articular pathway is outside the normal range	Yes	<0.05	-2.1	5
		No		+2.0	
	Cramps in the head, neck, and throat	Yes	<0.05	-4.6	4
		No		+1.4	
	History of orthodontic treatment or selective teeth grinding	Yes	<0.05	-4.5	4
		No		+1.3	
	Serious accidents, history of intubation	Yes	<0.05	-4.3	4
		No		+1.2	
	Disorders of the masticatory muscles	Yes	<0.05	-4.0	4
		No		+1.1	

Table 1. Cont.

Factor rank	Clinical indicators, units of measurement	Gradations	p	Predictive value (pat)	Strength of impact (%)
	Previous dental treatment	Yes	<0.05	-5.1	3
		No		+3.6	
	Pathology of hard tissues of the teeth	Yes	<0.05	-2.9	3
		No		+3.2	
	Misalignment of the centers of the dentition	Yes	<0.05	-2.8	3
		No		+3.0	
	Misalignment of the centers behind the lip frenulum	Yes	<0.05	-2.6	3
		No		+2.8	
	Patient's perception of the seriousness of the condition	Yes	<0.05	-1.2	3
		No		+2.4	
	Posture disorders	Yes	<0.05	-0.9	3
		No		+0.6	
	No need for treatment in the patient's perception	Yes	<0.05	-0.8	3
		No		+0.4	
	Features of the psychological state	Yes	<0.05	-0.6	2
		No		+0.6	
	Presence of comorbid pathology	Yes	<0.05	-0.3	2
		No		+0.2	
	The length of the articular pathway is outside the normal range	Yes	<0.05	-0.2	2
		No		+0.2	
	Gamma outside the norm	Yes	<0.05	-0.1	1
		No		+0.1	
	Peak excess of the average speed	Yes	<0.05	-0.1	1
		No		+0.1	
	Travel time outside the normal range	Yes	<0.05	-0.1	1
		No		+0.1	

Source: compiled by the authors of this study

and specificity values comparable to or exceeding those reported for isolated kinematic or imaging markers in recent literature. Embedding this algorithm into a WordPress-based application transformes statistically dense insights into a pragmatic tool that can be deployed in general dental practice with minimal training.

The clinical implications are substantial. Early identification of high-risk patients enables clinicians to intensify conservative care, expedite imaging or refer for surgical consultation before irreversible remodelling develops. Conversely, confidently categorising low-risk cases may prevent overtreatment and reduce healthcare costs. The indeterminate category – often overlooked in binary models – encourages evidence-guided watchful waiting and targeted re-evaluation, aligning diagnostic reasoning with real-world uncertainty. Notably, the web tool's automated calculations mitigate human error and facilitate multicentre data sharing, fostering a learning-health-system approach to TMJ care.

Several limitations temper these conclusions. The retrospective, single-country design raises concerns about referral bias and ethnic or behavioural heterogeneity. Follow-up was limited to one year, precluding appraisal of long-term joint adaptation and treatment durability. Moreover, psychosocial factors, although included, were assessed through broad proxies; finer-grained measures of stress, sleep, or nociplastic pain could sharpen prognostication. Lastly, machine-learning classifiers might capture non-linear interactions that sequential analysis overlooks.

Future research should test the algorithm prospectively across diverse populations, extend observation windows beyond five years, and compare performance against neural-network or Bayesian approaches. Inte-

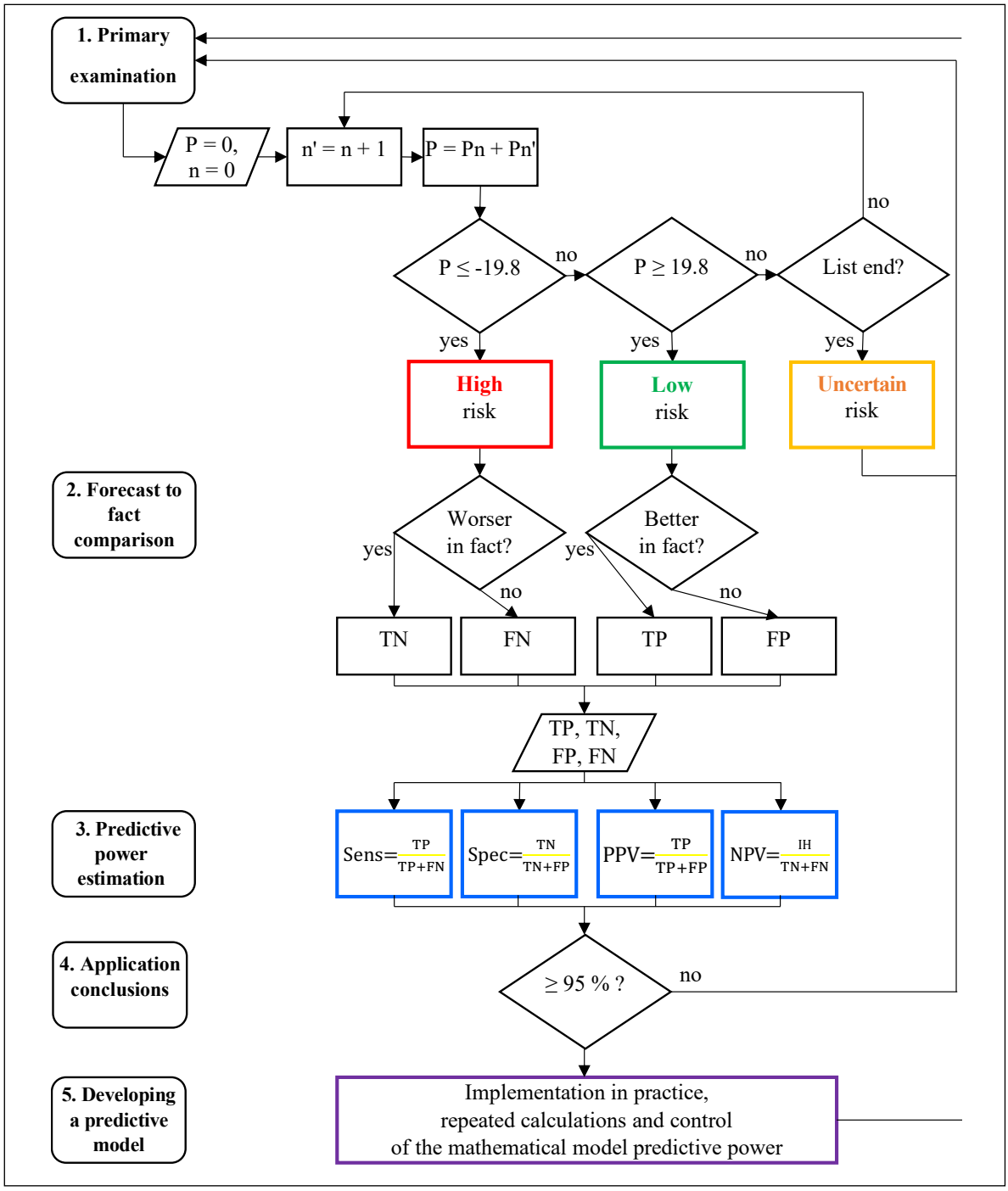

Fig. 1. Method (algorithm) for assessing the probability of progression of temporomandibular joints diseases and its prognostic power

Notes:

1. P is the predictive value of the indicator (pat);
2. n – rank of the factor;
3. TP – true positive results (positive both forecast and reality);
4. TN – true negative results (negative both forecast and reality);
3. FP – false positive results (positive forecast, negative reality);
4. FN – false negative results (negative forecast, positive realities);
5. Sens – sensitivity;
6. Spec – specificity;
7. PPV – positive predictive value;
8. NPV – negative predictive value

Source: compiled by the authors of this study

Table 2. Results of calculations by the method (algorithm) for assessing the probability of progression of temporomandibular joints diseases and its prognostic power in comparison with the data of actual patient observation

Progression in fact	Predictive risk assessment						TOTAL	
	Minimal		Uncertain		High			
	Abs.	%	Abs.	%	Abs.	%	Abs.	%
Yes	–	–	1	14	6	86	7	100
No	2	50	1	25	1	25	4	100
TOTAL	2	18	2	18	7	64	11	100

Source: compiled by the authors of this study

gration with wearable jaw-motion sensors and electronic health-record platforms could further personalise risk estimates. By iteratively refining both the mathematical core and its digital interface, we anticipate a new standard of precision-guided, patient-centred management for TMJ disorders.

Thus, in the theory and practice of clinical dentistry, prognostic algorithms expand the arsenal of tools and increase the effectiveness of predicting the risk of developing and progressing TMJ disorders, which makes it advisable to use them in practice in such patients.

CONCLUSIONS

1. Supplementation of clinical (anamnestic, physical) data with psychosocial and condylographic indicators allows to individualize the approach and increase the clinical effectiveness of the prognostic model of TMJ disease progression;
2. The algorithm for assessing the probability of progression of TMJ diseases and its prognostic power (applied by the method of sequential Wald analysis) is acceptable and clinically relevant. It takes into account not only binary conclusions, such as "high risk" or "low risk", but also intermediate values when the risk remains "undetermined". This approach is closer to real-world clinical thinking, where, in the absence of sufficient certainty, a physician can reasonably order additional tests or follow-up to clarify diagnostic or prognostic conclusions;
3. To evaluate the clinical effectiveness of the algorithm for assessing the likelihood of progression of TMJ diseases, it is appropriate and sufficient to calculate such indicators as sensitivity, specificity, as well as positive and negative predictive potentials using a standard method. This provides the possibility of objective control of the entire spectrum of clinically important aspects at both the individual and cohort levels;
4. It is recommended to apply the developed modified program of patient examination, which, along with standard methods, includes the use of clinical, condylographic and articulation diagnostic methods, as well as mathematical prognostic modeling using an algorithm for assessing the probability of progression of TMJ diseases.

Prospects for further research include replenishment of the primary data base, improvement of mathematical models, testing and implementation of individualized prognostic algorithms for assessing the progression of TMJ diseases with further determination of their clinical effectiveness.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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